TITLE: Feed arrangement for a subscriber loop with multi-level current regulation capability

FIELD OF THE INVENTION

The present invention relates to a feed arrangement for a telephone subscriber loop. More specifically, it pertains to a feed arrangement for controlling the subscriber loop current in dependence of the number of Customer Premises Equipments (CPE) active on the loop.

BACKGROUND OF THE INVENTION

With the arrival and expansion of the Information Highway, telephone networks have been slowly converted from an all-analog environment to a virtually all-digital network. Within these networks, the trunks and switches have been virtually 100 percent converted. However, the local loops leading to the customer remain largely analog, specifically the analog loop connecting the Central Office (CO) of the Public Switched Telephone Network (PSTN) to the subscribers' CPE.

Within the traditional telephone networks, a copper loop (or two-conductor cable), known as the subscriber loop, connecting the CO and the CPE is used to provide the POTS, whose signals are Voice Frequency (VF) signals in the frequency range of 0-4 kHz. The subscriber loop is capable of carrying signals up to several MHz, depending on its length and type. The two conductors of the subscriber loop are referred to as the TIP and RING, providing Plain Old Telephone Service (POTS) at both the subscriber premise and the CO.

Most CPEs draw DC current from the subscriber loop that connects them to the CO. For satisfactory operation,

a typical CPE requires a current in the range of 18 mA to 50 mA. This DC loop current is provided by the 52 V CO power supply, whose terminals are typically coupled to the subscriber loop via a feed arrangement including two feed resistors. The DC resistance measured between the TIP and RING of the subscriber loop (including the CPE), also referred to as external resistance, is typically in the range of 100 to 1900 ohms and depends upon the length of the subscriber loop. To provide sufficient loop current for the operation of the CPE with the longest subscriber loop, the value of the feed resistors is typically limited to 200 ohm each. In this case, the loop current is calculated to be I_{loop} = 52 V / (400 + 1900) ohm = 22.6 mA, which is above the minimum current required for proper operation of the CPE. In the case of a short subscriber loop, one having a resistance of 100 ohm, the loop current is I_{loop} = 52 V / (400 + 100) ohm = 104 mA, which exceeds the desired range of loop current for proper CPE operation. In addition, this high value of DC loop current results in an excessive amount of power dissipation and consumption by the subscriber loop feed arrangement, specifically 4.32 Watts and 5.40 Watts, respectively.

A technique that has been employed with success to limit subscriber loop current to a threshold value, and consequently limit power dissipation and consumption, is described in U.S. Patent No 5,333,196, which issued July 26, 1994 to Jakab and was assigned to Northern Telecom Limited. The contents of this document are incorporated herein by reference. The feed arrangement limits the DC loop current on short loops to a lower value, for example 30 mA, which in turn limits the power dissipation.

While the arrangement taught by Jakab does successfully limit the loop current and reduce the level of power dissipation and consumption, there is still room for improvement, in particular in instances when more than one CPE is connected to the subscriber loop. For example, when a first CPE is connected to the subscriber loop and then an additional CPE is switched on the subscriber loop, the current demands change significantly since the external resistance of the subscriber loop abruptly changes.

The background information provided above clearly indicates that there exists a need in the industry to provide a feed arrangement for a subscriber loop with an advanced current regulation capability capable of supporting multiple CPEs that can become active at any given time.

SUMMARY OF THE INVENTION

In a broad aspect the invention provides a feed arrangement for a telephone subscriber loop. The feed arrangement has a control element that can regulate the magnitude of the current in the subscriber loop to a target value selected in a set of target values, in dependence upon a number of CPEs active in the telephone subscriber loop.

The advantage of this feed arrangement is a reduction of power consumption when one CPE is active on the subscriber loop, while allowing for an automatic adjustment of the current when an additional CPE becomes active.

In a specific example of implementation, the feed

arrangement has an input that connects to a power supply, such as a Solid State Line Interface Circuit (SLIC). The control element has provisions to assess the magnitude of the current in the subscriber loop. On the basis of the current magnitude the control element generates an output control signal that determines the voltage that the power supply will generate. The voltage is controlled such as to regulate the magnitude of the current in the subscriber loop to a first target value when only one CPE is active in the loop, and to a second, higher target value when an additional CPE becomes active in the subscriber loop.

In a possible variant, the feed arrangement can be designed to accommodate more than two CPEs. In such case, the magnitude of the current can be increased stepwise for any additional CPE that becomes active in the subscriber loop.

The control element can be implemented in software on any suitable computing platform. The software logic is designed to observe the current in the subscriber loop to derive the number of CPEs that are active in the subscriber loop. When one CPE is connected in the subscriber loop and then suddenly another CPE becomes active, the external resistance of the subscriber loop diminishes abruptly. This results in an increase of the current in the loop. This increase is detected by the control element and interpreted as the actuation of an additional CPE. As a result, the control element then switches to a different current target value and adjusts the output control signal that regulates the power supply, accordingly.

In a possible variant, the control element can be

implemented in hardware, instead of software.

In another aspect the invention provides a method for regulating the magnitude of the current in a subscriber loop. The method comprises regulating the magnitude of the current to a first target value when a first CPE is connected to the subscriber loop and regulating the magnitude of the current to a second target value, higher than the first target value when at least one additional CPE is connected to the subscriber loop such that the subscriber loop feeds at least two CPEs simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of examples of implementation of the present invention is provided hereinbelow with reference to the following drawings, in which:

Figure 1 is a block diagram of a feed arrangement in accordance with a specific and non-limiting example of implementation of the invention;

Figure 2 is a flow chart that illustrates the process implemented by a control element of the feed arrangement of Figure 1 to regulate the current in the subscriber loop; and

Figure 3 is a block diagram of a computing platform to implement in software the process illustrated in Figure 2.

In the drawings, embodiments of the invention are illustrated by way of example. It is to be expressly understood that the description and drawings are only for

purposes of illustration and as an aid to understanding, and are not intended to be a definition of the limits of the invention.

DETAILED DESCRIPTION

Figure 1 illustrates a feed arrangement 10 constructed in accordance with a specific and non-limiting example of implementation of the invention. The feed arrangement 10 is designed to supply electrical power to a subscriber loop 12 on which one or more CPEs 14a, 14b, 14c, etc. may become active at any given time. The subscriber loop includes a TIP conductor and a RING conductor. When a CPE 14a, 14b or 14c connects to the telephone subscriber loop 12 it is connected across the TIP and RING conductors of the telephone subscriber loop 12.

The feed arrangement includes an input 16 that connects to a DC voltage power supply 18. The power supply 18 can be a SLIC circuit that is of a type known in the art, or of any other suitable variety. The power supply has an input 20 to receive a control signal for regulating the magnitude of the DC voltage that the power supply 18 applies at the input 16.

The feed arrangement 10 has a pair of power supply rails; namely a TIP power supply rail 22 and a RING power supply rail 24. The power supply rails 22, 24 terminate at an output 26 at which the TIP and the RING conductors of the subscriber loop connect. The power supply rails 22, 24 include current limiting resistors 28, 30.

The feed arrangement includes a control element 32

that regulates the DC voltage generated by the power supply 18 for, in turn, regulating the magnitude of the current in the subscriber loop 12. The control element 32 has a first input 34 and a second input 36 that connect to the current limiting resistors 30, 28 respectively, to receive the voltage drop at those resistors. Since the value of the resistors 28, 30 is fixed and known, the current in the respective power supply rails 22, 24 can be computed. On the basis of the signals applied at the inputs 34 and 36 the control element 32 generates a control signal at output 38 that is applied at the input 20 to regulate the magnitude of the DC voltage produced by the power supply 18.

The logic that defines the functionality of the control element 32 is illustrated by the flowchart at Figure 2. The process starts at step 40. At step 42 the control element reads the current in the TIP power supply rail 22 (which is the same as the current in the TIP conductor of the telephone subscriber loop 12). As discussed previously, this is done by observing the voltage drop at the resistor 28 and then dividing it by the value of the resistor 28. At step 44 the same process is repeated, this time in connection with the RING power supply rail 24 (the current is the same as the current in the RING conductor of the telephone subscriber loop 12). At step 46 an average value of the currents in the TIP and in the RING power supply rails is computed.

At decision step 48 the average current value is compared to a target value. The target value is set such that the current in the subscriber loop 12 will be sufficient to power a single telephone instrument 14a, while low enough to avoid an excessive power dissipation

at the feed arrangement 10 and also to limit the power consumption. In one specific example, the target value for the average current magnitude when a single CPE 14a is connected to the subscriber loop 12 is of about 18 mA.

If decision step 48 is answered in the negative, i.e. the average current magnitude in the subscriber loop 12 is very close to the target value, no further action is taken and the process resumes at step 40 for another execution cycle. On the other hand, if the average current magnitude in the subscriber loop 12 is not identical to the target value, the process computes at step 50 the rate of change of the current magnitude from the previous current value read during a previous execution cycle.

At decision step 52 the rate of change is compared to a threshold. This decision step is designed to detect if an additional CPE has become active on the subscriber loop 12. If no additional CPE has become active on the subscriber loop and the latter powers only the CPE 14a, then the average current in the subscriber loop will vary little over time and if variations occur they will be slow (small rate of change). On the other hand, if an additional CPE (for the sake of this example say telephone instrument 14b) becomes active, the external resistance of the subscriber loop, i.e., the resistance as seen from the output 26, will diminish abruptly in light of the fact that two CPEs are now connected in parallel. Accordingly, the average current in the subscriber loop will increase in magnitude significantly and will do so at a high rate. The value of the threshold is selected such that current variation rates that do not result from the activation of an additional CPE are below the threshold, and current variation rates that result from the activation of one or

more additional CPEs are above the threshold.

If the decision step 52 is answered in the negative, the process continues at step 54 where a control signal is generated at output 38 to reduce the value of the difference observed at step 48 between the average current magnitude and the target value. Any suitable feedback error reduction algorithm can be used without departing from the spirit of the invention. The output signal generated at step 54 is applied to the input 20 of the power supply 18 such that the DC voltage of the power supply will vary sufficiently to compensate for the error in the current value.

In the alternative that the decision step 52 is answered in the affirmative, the process continues at step 56 that computes a new current target value. One possibility to assess the new current target value is to associate in a table different rate of current changes to corresponding current target values. The new target value is extracted from the table by inputting the observed current rate of change. This approach is flexible in that it creates a set of target values, where each target value is associated to a different number of CPEs that can go active at the same time in the subscriber loop. The number of target values in the set can vary without departing from the spirit of the invention.

Each target value is selected to provide enough current to properly feed the number of CPEs connected simultaneously on the subscriber loop, while avoiding excessive power dissipation and power consumption at the feed arrangement 10. In general, the higher the number of CPEs that need to be supported at the same time, the

higher the target value will be. In a specific and a non-limitative example, the current target value when two CPEs are active on the subscriber loop can be of about 30 mA.

The process illustrated at Figure 2 can be implemented in software on any suitable computing platform. A generic computing platform is illustrated at Figure 3. The computing platform includes a Central Processing Unit (CPU) 58 connected to a memory 60 by a data bus 62. The memory 60 contains the program instructions that when executed by the CPU 58 implement the functionality of the control element 32 described earlier. An Input/Output (I/O) interface 64 also connects to the data bus 62 to extract or deliver signals that the control element 32 exchanges with the external world, such as the signals at inputs 34, 36 and the signal at output 38.

In one possible variant, the current in the subscriber loop is assessed simply by observing the voltage drop at one resistor 28, 30 instead of at the two resistors 28, 30. This alternative yields acceptable results since in most cases, the current in the TIP power rail will be the same as the current in the RING power rail.

Another possible variant is to realize the control element 32 in hardware instead of in software.

Although various embodiments have been illustrated, this was for the purpose of describing, but not limiting, the invention. Various modifications will become apparent to those skilled in the art and are within the scope of

this invention, which is defined more particularly by the attached claims.